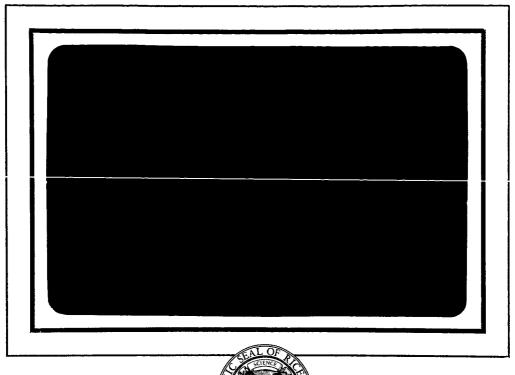
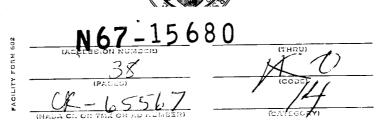
1/ana CB 65567







DEPARTMENT OF

SPACE SCIENCE



CENT PRICE(S) &





RICE UNIVERSITY HOUSTON, TEXAS

FINAL REPORT

NASA Contract NAS9-4822

Electron and Proton Spectrometer

Feasibility Study

and Breadboard Fabrication

LIBRARY COPY

DEC 27 1966

MANNED SPACECRAFT CENTER HOUSTON, TEXAS

National Aeronautics and Space Administration Manned Spacecraft Center

by

Brian J. O'Brien Principal Investigator

Department of Space Science
Rice University
Houston, Texas

1. General

This is the final report of the prime contract NAS9-4822 which commenced July 1, 1965 and terminated 31 August 1966. This contract called for design, construction, calibration and testing of a versatile detector of charged particles for possible utilization in manned spacecraft missions, specifically in ALSEP. This task has now been successfully accomplished, and the resultant instrument is code-named SPECS for Switching Proton Electron Channeltron Spectrometer.

Two SPECS instruments have been delivered to the Manned Space-craft Center at the termination of this contract. In accordance with Amendment #2, which resulted in a cost reduction of \$10,000, a data encoder is not included in these units (although all necessary preamps, switching logic, etc. are).

The instrument has been developed to the point where its capabilities and versatility are far superior even to those envisaged by the Principal Investigator (PI) in his initial proposal. The instrument is finding a multitude of applications, and in particular, it is slated for inclusion in an ALSEP (Apollo Lunar Surface Experiments Package) associated with a manned lunar landing.

2. Need for the Instrument

Since the launch of Explorer 1 in 1958, the most active discipline in space research has been that of Fields and Particles.

Several hundred instruments have been flown in scores of satellites and space probes, and the non-thermal charged particle environment of the earth has been explored in some detail. Intense fluxes of electrons and protons with energies between tens of electron volts (ev) and hundreds of kilovolts (keV) have been found in the Van Allen radiation zones, in auroras and in interplanetary space (e.g. see Figure 1). The lower-energy particles have been measured with plasma probes and Faraday cups, etc. [Snyder and Neugebauer, 1964, Gringauz, et al., 1965] while conventional devices such as geiger tubes and scintillation detectors and solid-state devices have been used to detect the more penetrating particles with energies of some keV [see McIlwain, 1960; O'Brien, 1963; Friedland et al. 1961; Sharp, et al., 1964].

However, to date there has been a largely unfulfilled two-fold need for a single instrument that can measure particles of all the energies sketched in Figure 1. On the one hand, the energy range of ~keV to tens of keV has been relatively neglected because it falls neither in the plasma nor the penetrating radiation category. And on the other hand, the usual space-borne instrumental constraints of limited weight, size and power render it desirable to have a single instrument that can measure all the categories shown in Figure 1. Accordingly, we proposed and entered into Contract NAS9-4822 for the development of such a device code-named SPECS for Switchable Proton Electron Channeltron Spectrometer. With a total weight of about 2 lbs, a power dissipation of about 1 watt and a size of less than 100 cubic inches, this device makes an eighteen point differential energy spectrum measurement of electrons and of protons separately over the energy range of some 50 ev to

some 100 keV. With a dynamic range of over 100,000 to 1, the device can make this spectral analysis in a period that may be varied between less than one second and some tens of seconds. Furthermore, simple variations of low-level logic elements provide wide versatility of use of the instrument with telemetry and encoding systems of different capacities, as well as providing internal consistency and background checks.

3. Description of the Instrument

The device that has made this instrument possible is the channeltron secondary emission multiplier [Evans, 1965]. This is a thin tube whose interior is coated with or is a secondary-emitting surface. A potential of some 3500 volts is established from one end of the tube to the other. When a charged particle strikes the inner surface of the tube at the aperture (where the voltage has ground polarity) secondary electron(s) may be emitted. These are accelerated down the tube and produce further secondary electrons in turn, so that finally an overall gain of some 10⁷ to 10⁸ is produced. The resultant pulse is collected at the anode and amplified. In the SPECS device five Bendix Corporation C-shaped channeltrons of I.D..040" and O.D.060" and length 4.00" and one helical "funneltron" are used in a near-saturated-pulse mode. (The device could also be used in a current rather than in pulse mode.)

Five 270° channeltrons are mounted one on top of the other in the SPECS device and the helical funneltron is mounted as shown in Figure 2 and the photograph of Figure 3. The entrance slits provide collimating apertures to define beams of entering particles.

A pair of deflection plates between the inside slit and the channeltron apertures has a voltage V across it. At a given value of V = V₁, particles of a given electrical charge (e.g. electrons, say) that

enter through the slits may be deflected into one or other of the five channeltrons if their energies are within the appropriate passbands E_{1i} , E_{2i} E_{5i} . The device was designed so that E_{5i} is roughly ten times E_{1i} , so that an energy range of a decade is sampled in five energy passbands at a given setting of the deflection voltage V. When electrons of these energies are deflected into these five small apertures, protons in a broad but similar energy range roughly E_{2i} to E_{4i} are deflected into the funneltron. The voltage V_{i} is stepped through ± 35 , ± 350 , and ± 3500 volts. Typical energy passbands are shown in Figure 4. When the polarity on the deflection plates is reversed, now electrons will enter the funneltron and protons will enter the five channeltrons.

The device thus has the following merits:

- (a) it makes electron and proton measurements simultaneously
- (b) it makes wide-band and multiple narrow-band measurements so that there are both internal consistency checks and also a greater sensitivity to smaller intensities of particles.

There is a further internal consistency check evident in the energy passbands shown in Figure 4. When the deflection voltage is (say) +35 volts, the highest energy channel detects particles with energies covered by the three lowest energy channels of the instrument at a deflection voltage of +350 volts.

4. High-Voltage Switching Power Supply

The high-voltage switching power supply (HVSPS) proved technically a very difficult device to build within the given restraints of weight, power, size, reliability, rapid switching with little transient or ripple effects, and so on. Considerable effort over a period of one year was given to both in-house studies and two parallel subcontracts to commercial vendors. Specifications of the final units are summarized in Table 1.

Units manufactured by Vendor A are being used by us for rocket flights, while the more expensive ones of Vendor B are more favored for satellite and lunar missions. Block diagrams of the two design approaches are shown in Figures 5 and 6. It may be noted that Vendor B also provides the regulated +3500 volts and 20 µamps to power the channeltrons. For Vendor A a subsidiary pack is used because of an unduly large transient induced upon switching if the +3500 volts is common to the HVSPS.

Switching of the HVSPS is accomplished either by external synchronizing signals or by an internal free-running clock.

4.1 Vendor A

Vendor A System block diagram is shown in Figure 5. The system consists of one feedback type regulator supplying a d.c. drive level to one of three switching transformer drive circuits. Each of the three transformers supplies 3.5 kv to the constant channeltron load via diode adding circuits. A sample chain on this output completes the feedback and maintains the output voltage at a constant value.

When Tl is energized one polarity is provided for the deflection system, and when T3 is energized the opposite polarity occurs: i.e. Tl corresponds to +3500 VDC on one deflection plate and T3 corresponds to +3500 VDC on the other deflection plate. When T2 is energized, two +350 volt supplies are generated which can be applied to either plate and attenuated to 35 volts by the high voltage transistor switches.

The cycle for switching in this system is as follows: +35V, +350V and +3500V on one deflection plate, and then +35V, +350V and +3500V on the other deflection plate. As can be seen from the switching cycle, the deflection plate voltage must be discharged from +3500 VDC to ground. In this system, the discharge occurs through an RC network. In an effort to

decrease the fall time, the deflection voltage is discharged towards -2000 VDC.

The switching logic for this system consists of an oscillator (free-running or external sync), three flip-flops and associated gates.

Delivery of the units was several months behind schedule. Operation of Vendor A system to date has not been completely satisfactory. Table 1 lists specifications achieved by this system. Nevertheless, more than ten of the units have been procured at this time, and although they are not deemed optimum for satellite or ALSEP usage, all together fifteen flight units of this model are being procured largely for rocket projects funded under Contract NASr-209. The first flight will be in a Javelin rocket at Fort Churchill in November 1966, and eight more will be flown in Javelins in 1967.

4.2 Vendor B

It became apparent in the first quarter of 1966 that the Space Craft, Inc. HVSPS, while being adequate for many purposes, was not capable of the high level of reliability, the rapid switching, small transients, etc. envisaged for ALSEP and long-life space applications such as in satellites.

Consequently, when our prime ALSEP Contract NAS9-5884 was negotiated, we were able to proceed on a parallel development project with Analog Technology Corp. The prime Contract NAS9-4822 covered by this report was used with NAS9-5884 to let a subcontract for design, development and test of a HVSPS and package design of a prototype. So successful were the vendors with the breadboard (e.g. they met a design goal of 10 msec switching time versus the contract specifications of 100 msecs) that a subcontract was let for fabrication of two

prototypes. Although these ATC prototypes were funded under NAS9-5884 and NAS6-1061 rather than under this particular prime contract, nevertheless this contract NAS9-4822 had a major share in development of this very successful supply whose prototype has now been accepted by Rice. Therefore, it is deemed proper to include analysis of this ATC unit in this report.

Since deflection voltages must remain stable versus time and temperature in order to facilitate accurate interpretation of the data, the use of operation amplifier techniques is proposed in order to provide accurate, stable amplification of the system reference voltage. Vendor B system block diagram is shown in Figure 6. The amplifier is a typical, inverting type operational amplifier configuration. The transfer function of this amplifier is given by:

$$A_{F}(p) = \frac{E_{O}}{E_{ref}} = \frac{-R_{F}}{R_{I}(1+pR_{F}C_{F})} \frac{1}{1 - \frac{1}{A(p)} \left(1 + \frac{R_{F}}{R_{I}(1+pR_{F}C_{F})}\right)}$$

A_r = Closed loop gain

A(p) = The amplifier forward gain

 $R_{\mathbf{F}}$ = The feedback resistor

 $C_{_{\rm F}}$ = The feedback capacitor

 R_{T} = The input transfer resistance

P = Laplace transform operator

For the loop gain

$$F = A(p) \frac{R_{I}}{R_{I} + R_{F}} >> 1,$$

$$\frac{E_{o}}{E_{ref}} \cong \frac{R_{F}}{R_{I} (1+p\tau_{F})}$$

where

$$T_F = R_F C_F$$

which is independent of amplifier gain. The amplifier transfer function is then a function of the passive components R_F , C_F and R_I only. Furthermore, the fractional change in the closed loop gain due to changes in forward amplifier gain is given by

$$\frac{dA}{AF} = \frac{1}{1-F} \quad \frac{dA}{A}$$

indicating that changes in the closed loop gain due to changes in the forward gain are reduced by the magnitude of the loop gain. This is an important consideration in a system of this type, which must operate over wide temperature extremes with resultant changes in active device parameters. The proposed configuration provides a dc feedback factor or loop gain in excess of 10^5 thus assuring the accuracy of the closed loop transfer function.

The deflection amplifier mechanism is shown in Figure 6. The device consists of a dual differential comparator amplifier followed by a power amplifier which drives two sine-wave-dc-to-ac converters. The inverters are followed by multistage voltage multipliers whose equivalent circuit is shown on the diagram. The outputs of the inverters are in series and of opposite polarity voltage. Feedback is applied through R_F and C_F to the amplifier summing function.

The resistor values R_6 , R_7 have been calculated in terms of R_F to obtain minimum power dissipation at ± 3500 VDC. Resistors R_1 through R_5 form the input current (I_{in}) which flows through the amplifier transfer impedance to form the proper output voltage. As specified, the amplifier input switches react to fixed level commands on one of 4 level command lines to gate the

proper input current magnitude into the amplifier and also to a fifth line which denotes polarity.

To understand the operation, assume level commands are gated in such that the output will be at +3500 volts. The error signal from the input comparator will be of such a magnitude and polarity to turn on the positive inverter and maintain the output at the desired level. If the positive input reference voltage is gated in, the positive inverter will be shut off and the negative inverter turned on to produce the desired output voltage. In this manner, the large bipolar output swing can be achieved without the use of multiple supplies and electromechanical switches. Because of the overall feedback loop, effects on the output voltage stability of diode conductance and leakage current, inverter switching transistor duty cycle and saturation resistance are attenuated by the large amount of loop gain preceding them.

Another significant feature of this mechanization is the excellent transient response provided by the feedback controlled differential inverter system. For the example shown, consider the output to be at +3500 volts. When the input signal is changed to force the output to +350 volts, the comparator error signal changes instantaneously (within bandwidth constraints) and the positive inverter turns off and the negative inverter turns on. The loop then forces the algebraic sum of the output voltages to be equal to the desired +350 voltage level.

A significant problem in a high-voltage sweep system occurs when a low ripple requirement is coupled with the need for rapid step response. The filter capacitors must be made large enough to reduce ripple to the desired level and yet the RC time constants of the filter capacitors will limit the rate at which the output will decay to a smaller voltage. In the

above example, the positive charge on $\rm C_1$ must discharge through $\rm R_1$. This would normally limit the response time in settling to the new level. However, in this system, the feedback loop will nearly instantaneously force the negative voltage to track the positive voltage in order to maintain the output at the desired level. Since the charge time of the inverter is only limited to the available transient drive power and switching transistor capability, a rapid transition can be made to a lower magnitude voltage. Because of this feature, the 1% ripple figure and the specification to step through six steps from -3500 to +3500 volts with switching times less than 30 ms can be achieved with low power drain. The measured 10 to 90% rise time of the system is 10 ms. This rise time is accurately controlled by the feedback shaping network $\rm R_F$, $\rm C_F$ and is therefore not susceptible to amplifier gain-crossover variation.

Examination of the output circuit will reveal that in the steady-state condition the negative inverter must operate at an output voltage somewhat greater than the desired negative voltage because of the attenuation of resistors R_1 and R_F . A similar condition occurs in the maximum positive excursion. The maximum power case occurs when the amplifier output is at ± 3500 volts.

A unique design feature in the amplifier mechanization is the use of Class-C tuned amplifiers, in lieu of conventional square-wave static inverters for generation of the high voltages. The tuned system is preferred for the following reasons:

(1) Losses are considerably smaller than those encountered in a square-wave system. Diodes and secondary winding capacitances, for example, are tuned by the transformer self-inductance and are not therefore loss-inducing elements as in the square-wave case.

(2) Noise production in signal-processing electronics (attributable to the high-voltage supplies) is reduced. Electrostatic shielding is more effective for sine-waves than for square waves. Transient ground currents are reduced in the Class-C system, and input current conduction peaks are longer and hence smaller than for square-wave systems.

In general, power supply-pulse amplifier crosstalk is much less a problem in a tuned sine-wave system. Further isolation enhancement is provided by local decoupling of ripple voltages and bypassing of curve currents.

The low-voltage conversion system consists of a two-core dc-to-ac inverter, which is boost-regulated against a stable dc reference voltage. This design approach has been chosen to avoid the attendant losses that occur when a series type regulator is used with an unregulated power source.

The design approach used here provides an efficiency of approximately 86%. Boost regulation using transistor switching techniques takes advantage of the speed and efficiency afforded by transistors when operated in their current-saturated and cut-off modes. The regulator illustrated in the block diagram (Figure 6) produces output voltages inversely proportional to the disconnect-diode conduction duty cycle. To insure that these output voltages are the desired values, one of them is compared against a stable reference and amplified. The result-ant signal is then used to adjust a pulse-width or duty-cycle regulator on one-half cycle of the inverter square wave. In this way, outputs that are too high or too low produce reduced or increased switching duty cycles, respectively. The accuracy with which the output is regulated is determined by the following:

- (1) the magnitude of the correction required between the unregulated input voltage (to the duty-cycle regulated switch) and the output, and
- (2) the quantity of feedback between the output and the power switch.

The effect of the boost regulation through variable duty-cycle switching is to produce a virtual transformer between the power source and the load. This is evidenced by the load power being reflected back to the power source as a constant volt-ampere product, regardless of source voltage. In addition, primary copper and switching losses are reduced by operating at lower currents.

The two-core inverter design approach is proposed because of the inefficiency of the conventional single saturable-core oscillator-inverter at this low power level. The two-core approach is preferred for the following reasons:

- (1) Core magnetizing effects in the power-transformer secondaries could disturb timing and regenerating in the primary if the transformer were also used as a saturable timing element.
- (2) In addition to isolating the timer from the load, the power transformer can be made more efficient if it is not a saturable element. Another advantage of the two-core oscillator is that it does not induce a large magnetic regeneration current spikes during each switching half cycle.
- (3) The saturable transformer is used exclusively for timing because such a circuit is simple, efficient, and does not require the duty-cycle adjustments sometimes required in transistor multivibrators.

The power conditioner also contains two important protective elements: a current limiter and an overvoltage protection diode. As shown in Figure 6, the current limiter is composed of transistors Ql and associated resistors and diodes. Under normal operation, Ql is saturated at 0.25 volts. voltage between the bus or battery +28-V line and the base of Ql is equal to the sum of the emitter diode drop of Ql plus the IR drop across Rl. When the current through Rl produces a voltage tending to exceed one diode threshold, the voltage becomes limited by the regulating or clamping action of Dl, D2 and the current limit is consequently set at one diode threshold divided by Rl. In the event of a catastrophic short on the output of the current limiter, this configuration would have to stand full limit current at the highest supply voltage. Current limits are often set at 1.5 to 2.0 times normal running current. Limit stability over the required temperature range is about ±13%.

The protective diode, D3, fires in a current-limited mode when the input voltage is in excess of some acceptable limit. This limit level is usually in excess of the boost voltage, V_B . Table 1 lists specifications achieved by this system.

5. Channeltron Amplifiers and Discriminators

Circuit diagrams of the amplifier and discriminator are shown in Figure 7. Design constraints posed by the need for versatility included the absence of negative voltages for the low-level electronics. This unit operates satisfactorily from unregulated (28 $\pm \frac{5}{4}$) and (7 $\pm \frac{1}{1} \cdot 5$) volts battery supplies. Some simplification of the circuit is possible if this constraint is removed.

Operation of the amplifier is as follows. The signal is taken from the high voltage side of the channeltron, and this necessitates

a-c coupling between the channeltron and the amplifier. A standard boot-strapped cascode configuration consisting of Q1 and Q2 is employed in the charge sensitive amplifier. The resultant output of the charge-sensitive amplifier is coupled via emitter-follower Q3 to the base of differential amplifier Q4a.

The discriminator is a biased differential amplifier with positive feedback via the capacitor divider C8 and ClO. For no input signal the base of Q4b (one side of a matched differential transistor pair) is biased 200 mv above Q4a, resulting in Q4b conducting with Q4a cut-off. The reference voltage for the diff-amp is obtained from an FCT-1125 zener diode. Transistor Q5 is then off with Q6 saturated and Q7 cut-off, causing the output to rest at +7 volts. The standing currents are so chosen that, when an input pulse raises the base of Q4a by 200 mv, Q4a starts to conduct and Q4b ceases conduction. The collector of Q4a drops while the collector of Q4b rises. The output of Q4a is coupled to the base of Q5, turning Q5 on. The output of Q5 saturates transistor Q7 while the out-put of Q4b turns transistor Q6 off. The output then falls to VCE(SAT). Positive feedback via ClO forces this action to regenerate until the transistors (Q6 and Q7) are cut-off and saturated respectively. The charge on C8-C10 then decays through R17 until the two base voltages are again equal. Regenerative action then forces the output back to the quiescent level of 7 V.

The output pulse width is controlled by C8-C10 and R17. Rise and fall times are less than 200 nanoseconds. The triggering level of the discriminator is determined by the relative voltage of the base of Q4b compared to Q4a. This bias can be varied by adjusting R14. Pulse pair resolution of about 2 μ secs is achieved with this unit.

Power dissipitation per channel is 25 milliwatts. In all our applications to date, each channeltron is assigned its own amplifier and discriminator.

6. Switching Logic

If the particular spacecraft is telemetry limited, commutation between different channels is accomplished at the discriminator. Switching logic for a specific application is shown in Figure 8. In this system channeltrons 1-5 (CEM - 270° channels) are subcommutated while the output of channeltron 6 (8mm cone helix) is continuous.

A typical block diagram of the total instrument is shown in Figure 9.

7. Performance Verification

7.1 General

Performance of the instrument was verified by calibration with beams of electrons and of protons of different energies, and by examination of the rejection of Lyman- α ultraviolet radiation at 1216 Å, as well as by activation by miscellaneous radioactive sources.

The most extensive tests amounted to detailed calibration with beams of electrons of various energies fired at various angles to the instrument. The electron gun and accelerator for this purpose were specially designed and fabricated at Rice so as to provide a uniform but variable beam over a wide area.

7.2 Electron Accelerator

Two Penray mercury lights supplied ultraviolet light with peak intensity at 2537Å. The lights were shone on an aluminum plate six inches away, and there liberated photoelectrons with extraction energies $\lesssim 5$ ev. The plate was maintained at a negative potential (-V) equal to the requisite energy of the electron beam.

The electrons were then accelerated over a distance of six inches in a uniform and constant electric field until they passed through a 3.5 inch diameter screen. The uniform field was derived from eleven uniformly-spaced aluminum annuli with inside diameter five inches and with a voltage-dividing string of twenty-four 22 Megohm resistors.

The electron energy was then varied readily over the range $\sim\!30$ ev to 30 kev by means of the voltage applied to the photoemissive surface. The beam was found to be uniform in flux to within a factor of two over the diameter of 3.5 inches, which is more than adequate for the SPECS entrance apertures and which is indeed one of the best of those electron accelerators known to us. The electron flux was measured with a Rice-built Faraday cup, with a maximum flux of $\sim\!3$ x 10^{-11} amp cm $^{-2}$, sufficient to give count rates of high statistical accuracy in SPECS, corresponding to beam intensities of order 10^7 to 10^8 electrons cm $^{-2}$ sec $^{-1}$.

The energy dispersion of the electron beam was negligible, and the high-voltage power supply had sufficient regulation and limited ripple that the energy resolution possible was about 2%. This resolution was verified with the Faraday cup fitted with a retarding grid on which a variable voltage was applied.

SPECS detectors were calibrated for energy and angular response in a Veeco VS-400 vacuum chamber. Most of the calibrations took place at pressures between 5×10^{-6} and 1×10^{-4} mm Hg. The SPECS detector was mounted on a cart which can move $7 \frac{1}{4}$ inches, with position known to $\pm 1/\frac{10}{10}$ inch. The SPECS was rotated about its aperture in a plane perpendicular to the direction of motion of the cart. It could be rotated about 37 degrees with the position known to about ± 2 minutes. Mechanical feedthroughs made it possible to position SPECS while calibrating. Some calibrations were made automatically

using a motor to rotate SPECS and a potentiometer to measure its angular position.

Calibration of the energy passbands was done mainly in the plane of the channeltron array, i.e., over the smaller acceptance angle. The usual procedure was to rotate the instrument about a pivot point centered on the front aperture while maintaining a constant accelerating potential on the accelerator. Throughout the calibration the HVSPS was operated in a manual stepping mode so that a single SPECS deflection voltage (e.g. 350 volts) was applied during an entire sweep in angle. Typical calibration results are shown in Figure 10, and general curves were shown in Figure 4.

Geometric factors for the channeltrons could be derived in this manner to be of order $10^{-5}~{\rm cm}^2$ sterad.

7.3 Proton Calibration

Calibration with protons was achieved with a Rice - (NASr-209) Texas Nuclear 0 to 100 kv accelerator equipped with a paladium leak to admit hydrogen. The disadvantage of this compared to the electron accelerator was its relatively small beam-spot size, the presence of energetic neutral atoms and a high L_{α} glow.

Nevertheless, the unit was used to verify that the energy passbands for protons were the same as those for electrons when the deflection-voltage polarity was reversed. One would have been more than slightly perplexed if indeed this chargesymmetry had not been demonstrated as valid.

8.4 UV Rejection

One of the principal problems in the use of such devices with intrinsic energy threshold of only a few electron volts

is, of course, that they can respond not only to particles but also to ultraviolet light.

The spectral response of the channeltrons has been found to be ~1% at Lyman- α (the most intense solar emission in the hard UV) with efficiency falling off very rapidly at longer wavelengths. Consequently we chose to test SPECS by exposing it directly to L_{α} generated in the charge-exchange or RF excitation chamber of the Texas Nuclear accelerator.

The rejection ratio given by the SPECS housing compared with a directly-exposed channeltron was found to be in excess of 10^4 to 1. Thus, the direct rejection of solar L is more than 10 to 1 in the middle energy passband.

Consequently, the unit can look directly atgeocorona and have count rates of $\sim 1/\text{sec}$ or less. When the unmodified unit views the sun directly it will have a background count rate of $\sim 10^3$ counts/sec, but it is deemed certain that this can be substantially reduced by interior baffling, etc. if it is deemed necessary in a particular application.

In any event, it is important to note that the actual background in any environment is readily determined exactly when the deflection voltage V is reduced to zero by the programmable HVSPS.

8. Miscellaneous Comments

8.1 General

This brief report does not purport to cover in agonizing detail the learning curves followed in this contractual study. However, there are miscellaneous comments that are pertinent insofar as they were items discovered by Rice personnel during this study and utilized to produce the optimum configuration and the most effective instrumentation.

8.2 Handling of Channeltrons

Insofar as the individual channeltrons are small and brittle and expensive, careful handling techniques were evolved. Each channeltron was individually potted in a milled fixture (later in a molded fixture). Numerous substances were tested and high-impact styrene proved to be very satisfactory for the C-shaped units. Kel-F was used for the helical-shaped funneltron. The actual collector cap or anode was affixed with conductive solder by Rice and terminal wires were potted in situ with requisite blocking capacitor and resistive load. The entrance aperture of each channeltron, of course, was operated at ground potential so that very low energy particles of either polarity could be detected.

8.3 <u>Lifetime Tests</u>

Since the channeltrons are relatively new and untried devices, we carried out various lifetime tests by activation with standard UV and radioactive sources. Initially, some of the temporal changes observed were ascribed to contaminant coatings of the channeltron interior by diffusion pump oil from the vacuum systems (an effect of this kind certainly degraded the photoemissive surface in the electron accelerator). Accordingly, specially-clean Vac-Ion vacuum systems were employed for further tests, which are still underway (under Contract NAS9-5884).

Preliminary results indicate an <u>efficiency</u> decrease of ~20% in a period of a few minutes immediately after the high-voltage (~3500 volts) is applied each time. The efficiency then stabilizes, and if the high-voltage is temporarily switched off and then on again, it is found that the efficiency has recovered. This effect is not understood by us or by Bendix,

the manufacturers, and it is being studied further. It does not appear that tests by other groups have been in a position to detect this effect, viz with a clean vacuum system, pulse mode, good temporal resolution, etc. (see Figure 11).

Accumulated dose tests have also been performed to determine if there is an aging degradation. None has been detected to date with total accumulated counts of order 10^9 . Further tests are proceeding.

8.4 Channeltron High-Voltage

The potential to be applied to the channeltron is not very critical beyond $\sim\!3200$ volts, because this yields a pulse height distribution well above a nominal discrimination level of 15 millivolts. During very fast count rates of some 300,000 per second the average channeltron pulse becomes smaller. Therefore, for some applications where such fast rates are desired it may prove desirable to use a higher voltage (e.g. 4000 volts) so as to maintain large voltage pulses. Channeltron impedances range between $\sim\!500$ M Ω and and 2000 M Ω , with an average around 1000 M Ω and with a temperature coefficient of $-0.5\%/c^{\circ}$.

8.5 Special Configurations

Since the channeltrons are made of glass, they may be bent or molded in a wide variety of apertures, shapes and sizes, etc. so as to optimize to a given project. For example, in some projects we will replace the 1-mm diameter channeltrons (see Figure 3) with 1mm x 3mm channeltrons with the long side parallel to the slit so as to increase geometric factors. The tradeoff here does not appear to be in reliability or efficiency etc. but only in cost for special units.

8.6 Electrostatic Charge Build-Up

In early models of this instrument, it was noted that if it was placed in the large beam of electrons then the pass-bands would apparently gradually drift. This was diagnosed as being due to essentially space-charge effects distorting the deflection field and it was eliminated by providing electrical-conduction paths to ground for such exposed areas.

8.7 Analytical Derivation of the Energy Pass Bands

Conceptually one can calculate the energy passbands in ecah channel for a given deflection voltage by an analytical treatment of the electrical field between the plates and thence by deriving the particle trajectories. This was done very early in the contract.

However, it was recognized by us at the same time that such calculations did not take account of the non-trivial fringing fields. Therefore optimized configurations were designed and built and tested and the actual passbands derived by direct calibrations. They differed somewhat (as expected) from the analytically-derived passbands. This slight difference is in no way prejudical to the instrument, since the passbands were sufficiently similar to enhance the final confidence in the experimentally-derived passbands.

8.8 Environmental Conditions and Use

The complete unit operates with negligible (<5%) variation in its characteristics over temperatures from -20°C to +50°C, for input voltages from 24 volts to 33 wolts. It will be launched on different vehicles, with the most severe vibration and acceleration levels being associated with Nike-Apaches,

Javelins and Scout rockets. As discussed above, it is also being developed in an optimum configuration for the ALSEP program.

9. Conclusion

The instrument code-named SPECS developed under this contract and refined in parts under other contracts has proven to be a device that far exceeds the original design goal. For example, the addition of the funneltron (not envisaged in the Work Statement) has provided the extremely important capability of simultaneous observations of electrons and protons as well as a vastly-improved dynamic range. The capabilities of the HVSPS also pressed the state-of-the-art to a level hitherto unattained.

It is envisaged that this unit will permit an extraordinary single-sweep coverage of charged particle fluxes over an energy range of more than one thousand to one, and a dynamic range of some 10^8 to one. Therefore it will permit measurement of particle fluxes in the plasma, auroral, interplanetary and Van Allen domains of energy. It is thus ideally suited, for example, for space probes or projects (e.g. ALSEP) where the charged-particle environment is unknown.

APPENDIX 1

PERSONNEL

Personnel involved in this project included:

B. J. O'Brien
Professor

Principal Investigator

F. Abney
Electronics Engineer

Instrument Engineer

R. Trachta

Mechanical Engineer

Mechanical Designer

J. Godwin

Machine Shop Foreman

Mechanical Fabrication

J. Burch
Graduate Student

General design and calibration

R. Harrison Technician

General design, calibration and testing

T. Winiecki
Graduate Student

Electron gun design and

operation

R. Chappell
Graduate Student

UV rejection studies

R. LaQuey
Graduate Student

Low-level electronics design

APPENDIX II

COSTING

Estimated cost of this Cost Reimbursable (zero fee) contract was \$99,272, modified by Amendment #2 to be \$89,272. Actual costs incurred, with an overhead rate of 56.8%, were \$89,236, thus leaving a budgetary surplus of \$36, which has been allocated for the reproduction of this report.

APPENDIX III

PUBLICATIONS

A paper entitled "SPECS, A Versatile Detector of Low and High-Energy Charged Particles" by B. J. O'Brien, F. Abney, J. Burch, R. Harrison, R. LaQuey and T. Wini&ki is in the course of preparation to be submitted to an appropriate technical journal.

TABLE 1
HIGH VOLTAGE SWITCHABLE SUPPLIES

<u>Spacification</u>	<u>Vendor A</u>	<u>Vendor B</u>
Power	Constant 1100 mw	Avg-505mw; Peak-1092mw
Weight	0.89 lb	1.8 lb
Size	18 cu. in.	32 cu. in.
3500 V Rise Time	25 m.s.	8 m.s. (max.)
3500 V Fall Time	100 m.s.	8 m.s. (max.)
Switchable Rate	200 ms/level (max.)	100 ms/level (max.)
Transients on line	2 V pk-to-pk	0.2 V pk-to-pk (max.)
Ripple (Switchable Supply)	3 V pk-pk (35 volts) 6 V pk-pk (350 volts)	less than 1 V pp (in all levels)
	150 V pk-pk (3500 volts)	
Channeltron Supply	No	3500 V constant
Channeltron Supply	Ripple -	50 mv ·

REFERENCES

- Evans, D. S., Rev. Sci. Inst., 36, 375 (March 1965).
- Friedland, S. S., H. S. Katzenstein and F. P. Ziemba, Advances in Semiconductor Detectors for Charged Particle Space Spectrometry, <u>IEEE Trans. on Nuclear Science</u>, <u>NS-10</u>, 190-201, (January 1963).
- Gringauz, K. I., B. N. Gorozhankin, G. L. Gdalevich, N. M. Shutte, R. E. Rybchinsky, and V. V. Afonin, The Technique and Results of Experiments Conducted on the Cosmos 2 Satellite by Means of Langmuir Probes, Ion Traps of the Honeycomb Type and Photoemitters, Space Research V, 733-750, (1965).
- McIlwain, C. E., Scintillation Counters in Rockets and Satellites,

 IRE Trans. in Nuclear Science, NS-7, 159-164, (June-September,
 1960).
- O'Brien, B. J., Review of Studies of Trapped Radiation with Satellite-Borne Apparatus, Space Science Reviews, 1, 415-484, (1963).
- Sharp, R. D., J. E. Evans, W. L. Imhof, R. G. Johnson, J. B. Reagan and R. V. Smith, Satellite Measurements of Low Energy Electrons in the Northern Auroral Zone, <u>J. Geophys. Res.</u>, <u>69</u>, 2721-2730, (1964).
- Snyder, Conway W., and Marcia Neugebauer, Interplanetary Solar-Wind Measurements by Mariner II, Space Research IV, 89-113, (1964).

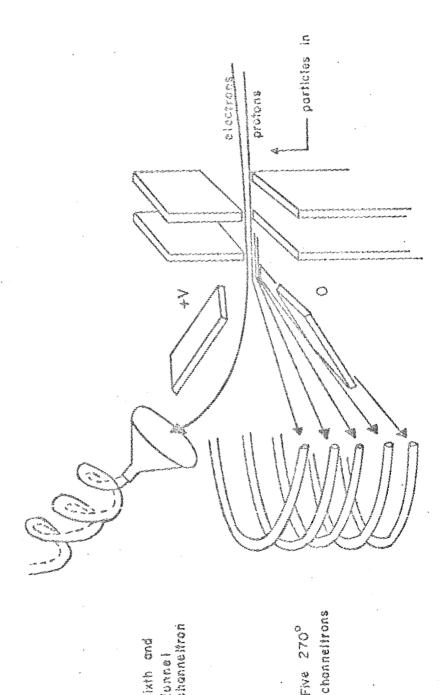
INIVINUSUACEA BOUNDALINE

<u> </u>	
	SOLAR COSMIC RAYS (PROTONS) P ZEZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZ
	VAN ALLEN RADIATION e ed
	AURORAL RADIATION e c c c c c c c c c c c c c c c c c c
.an capturation and an in 2 and an inches a law to analysis.	P CA CONTRACTOR WIND C CONTRACTOR WIND C CONTRACTOR WIND
	P EN ENTITION IN SOLAR WIND
<u> </u>	
5	
	FIGURE 1 P54118

Crotocrotopico descos Crotopico conociato

The first find the first find the first

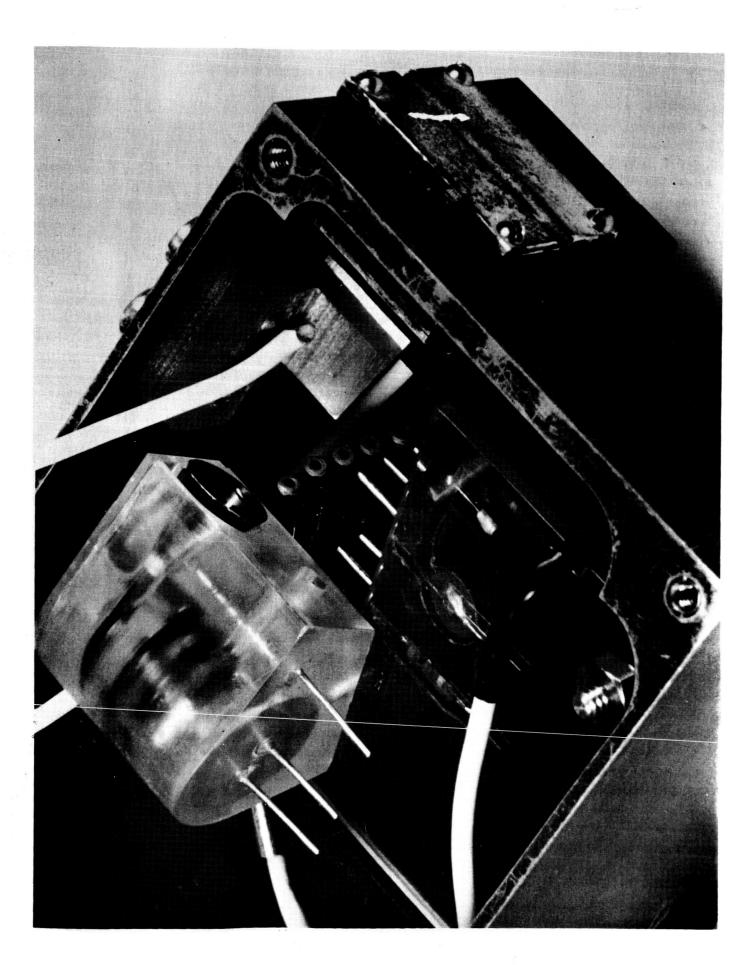
Electrons and protons with energy between 750 ev and 150 kev each in eighteen different energy sinces as voltage VOITS. 435, 4350 and 43500 な事になるは かのはのはかな



Fire 270°

" 我 我 我 我 我 我 我 我 我

可能 异类的



"SPECS"

ENERGY PASSBANDS OF

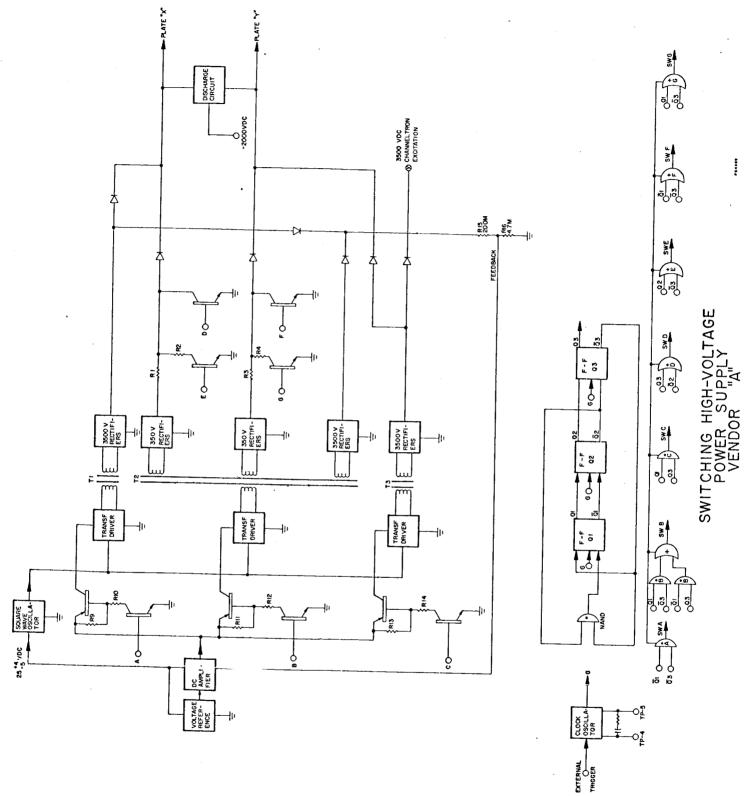
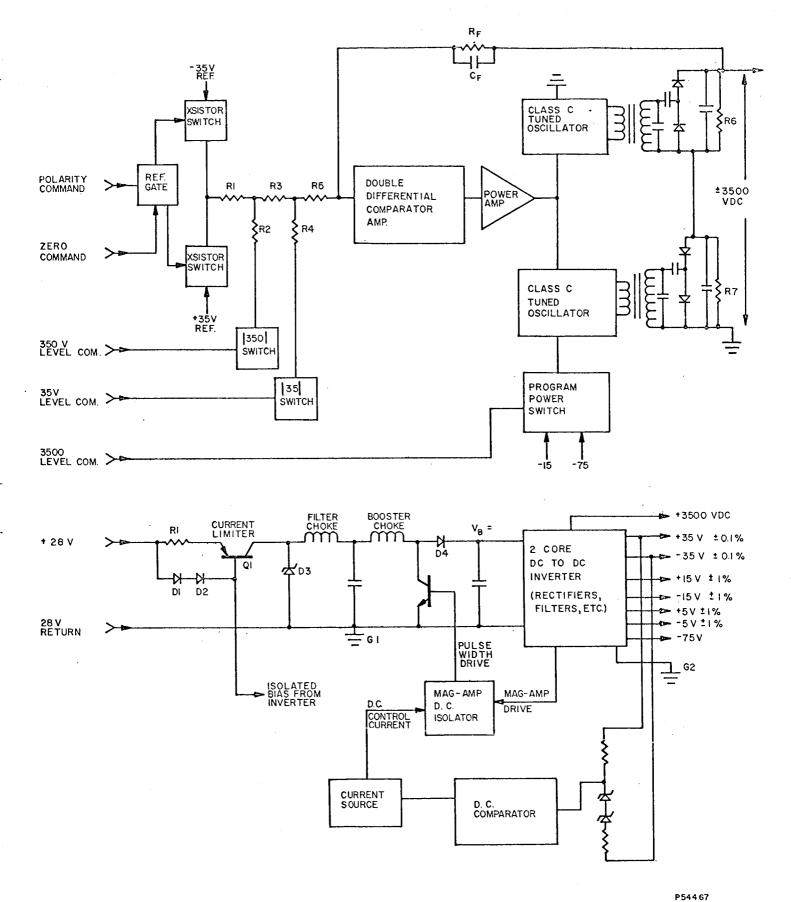
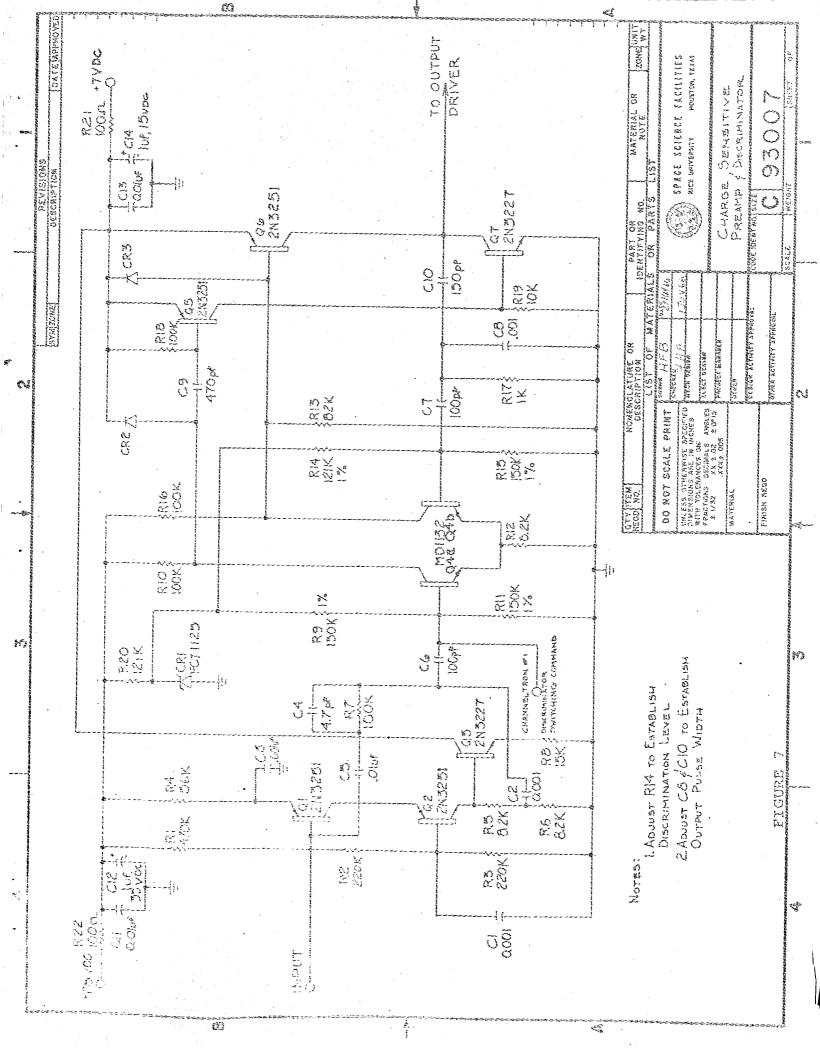


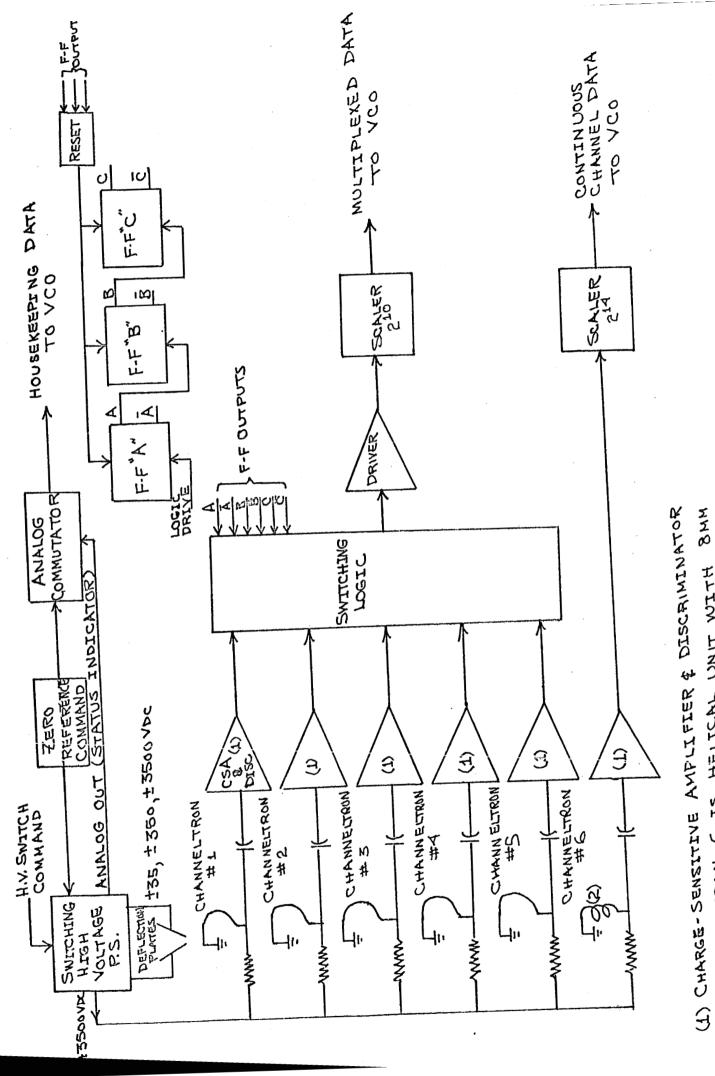
FIGURE 5



SWITCHING HIGH VOLTAGE POWER SUPPLY VENDOR "B"

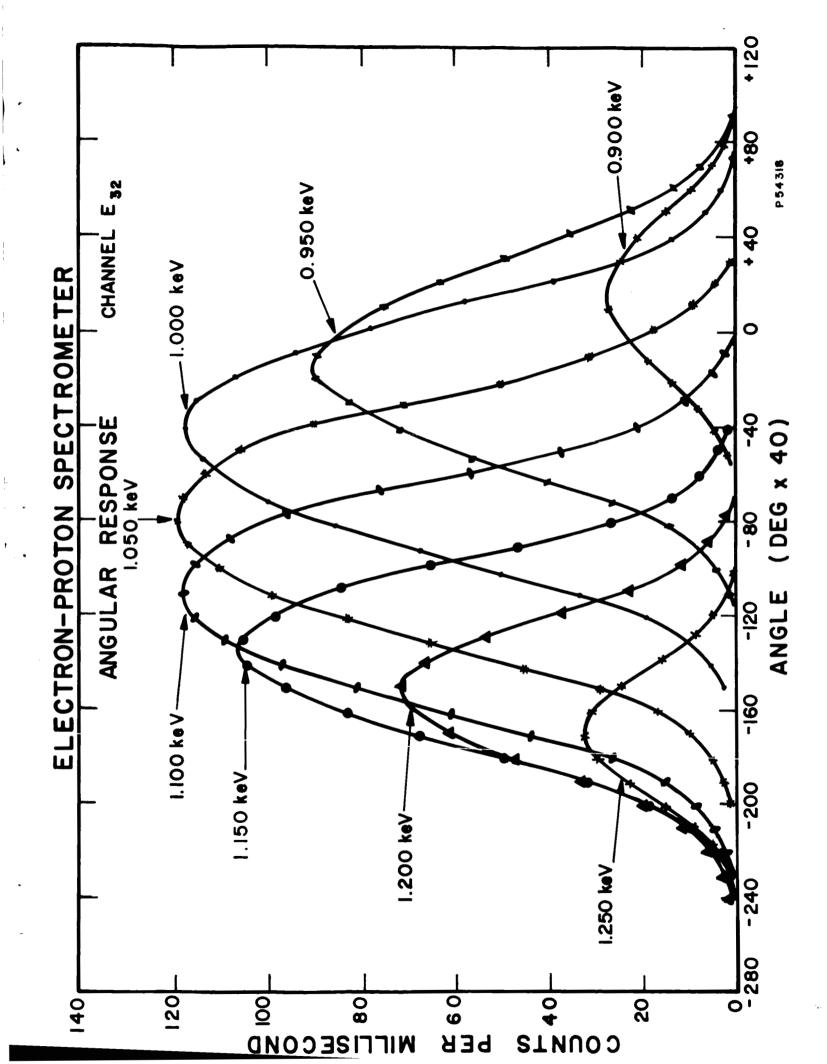


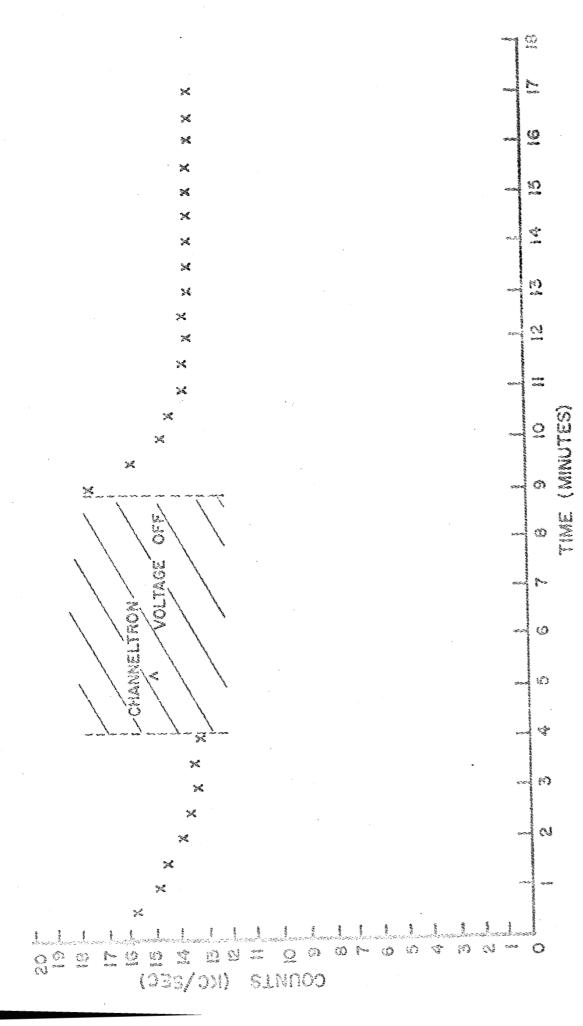
ENCOME



IS HELICAL UNIT WITH SAM CURVED 270 ALL OTHERS APERTURE CONE APERTURE. (2) CHANNELTRON 6 WITH TY SHM

FIGURE 9





TT BURGE